Image Processing Laboratory

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First and foremost, the Image Processing Laboratory engages in research and development of image-based pattern recognition including some areas of Artificial Intelligence, database organisation, retrieval, and robotics. More specifically, as can be seen from the background information and the recent research publications of the members of the laboratory, 2-dimensional Continuous Dynamic Programming for non-linear image matching, 3D image reconstruction, object tracking in a time-varying image, image retrieval from video data, and extracion of the Internet community are our current focus.

Related to the recent progress of the web, a huge amount of multimedia data without index becomes available to store in our PC's. However, no sophistcated methodology to manage such data has been developed so far. So that we are solicited to attach an index to each data. Our research aim is to develop algorithms to realize automatic annotation to real word data for integrated retrieval of multimedia information. The algorithms include self-organisation and transformation among representation of multimedia and feature extraction and recognition of real data. Real world data includes video, still image, speech, music, sound, and text each of which has not been indexed by labels.

An example of multimedia integration retrieval called "CrossMediator" developed by ten-year project (1992-2002) RWC of METI (Japan). Some parts of CrossMediator have been in the commercial market by through a private company. Prof. R.Oka was a chief of group which developed "CrossMediator". Our laboratory will pursue to develop more sophisticated functions which might reveal a new generation of the Internet. Speech retreival system used in CrossMediator is used for developing new types of commercial products. At the present time we

use two kinds of index for searching video data. One is used to obtain the target media from Youtube by using index. The other one is used for searching parts of the target data which are not indexed.

One of the recent progress is developing a set of algorithms for spotting recognition and tracking objects in a time-varying image. These algorithms enable to realize automatic anonotation of video image capturing moving objects. The most promissing algorithm called 2-dimensional Continuous Dynamic programming (2DCDP) was proposed by our laboratory. This enables to perform full pixel matching between images. The full pixel correspondene is used for reconstructing 3D shape from at least 3 images obtained from different viewpoints and also gives a quite precise features like optical flow from a motion image. The 2DCDP is also applicable to non-linear registration for medical images to extract different parts between normal CT imagesand abnormal CT images.

Another recent progress is developing a spotting algorithm for song wave retrieval. A large amount of song wave data is available for anyone along with the progress of storage hardware of music data. But the progress of technology for accessing the song wave data seems quite slow so that we must use conventional and not sophistcated tools. Our new software can provide users a convenient way to find and rerieve the song wave data by singing an arbitrary part of it which he/she wants to hear.

The Internet is regarded as a network composed of virtual communities. Visualization of the community is becoming an important research target. Our lab is developing a sophistcated algorithm based on so-called Associated hyper-linked word space (A-space). We use the algorithm to detect clusters each of which corresponds a virtual community. Visualization of each virtual community is realized by showing the content extracted from the web pages included the community.

On the other hand, we have carried out several research projects related to complex systems in which many independent components interact with each other and emerge global phenomena. Particularly, we have conducted on multiple robot control, and energy efficient walking control in biped robots.

With respect to multiple robot control, we have analyzed the dynamics of multiple mobile robots as a swarm under the mixture condition of long and short range communication, and evaluated the required amount of communication for the multiple robot control. Particularly, we have investigated the relation between the speed of convergence and the graph spectra induced from the swarm robot network, and we have developed a stable and fast swarm robot control method.

As implementing actual multiple mobile robots, we need a sensing system. In this project, we have developed a sensing and position estimating system for the robots, and evaluated the accumulated errors.

In terms of the walking control of biped robots, we have set the problem to walk down steep hills, which is known as steps of walking robots fall into chaotic and unstable one. We have developed a control method for the problem, and evaluated it with numerical experiments. The results show it is capable to walk down the steep slopes stably with less control energy consumption. is capable to walk down the steep slopes stably with less control energy consumption.

Refereed Journal Papers

Unrefereed Papers

[yaguchi-02:2012] Ian Wilson Keita Sano, Yuichi Yaguchi. Comparing L1 and L2 phoneme trajectories in a feature space of sound and midsagittal ultra-sound tongue images. *The Journal of the Acoustical Society of America*, 132(2):1934, September 2012.

Refereed Proceeding Papers

[naruse-02:2012] K. Naruse. Velocity Correlation in Swarm Robots with Directional Neighborhood. In *Proc. of the 12th International Conference (IAS-12)*, pages 843–851, 2012.

Most of robotic systems introduce a directionless neighborhood area, such as a circle or sphere, for robot communication and interaction because it reflects a natural property of some physical sensors and devices. On the other hand, it has reported that some of natural birds employ directional neighborhood for neighbor observation. In this paper, we introduce the directional neighbor to a robotic swarm system, and we investigate how it affects to the connectivity and stability of the system.

[naruse-03:2012] K. Naruse, E. Sato, and Y. Yaguchi. Development of Accommodation Facility Selection Recommendation System. In *Proc. of the 4th International Conference on Awareness Science and Technology (iCast2012)*, pages 207–211, 2012.

collaborative filtering recommends a list of items to a given user, to which he is expected to prefer to, considering a history of purchase items of the user and those of other users, and it is applied to many web shopping sites. On the other hand, although many people often reserve accommodation facilities from web pages, it is difficult to apply the collaborative filtering to accommodation selection because a smaller sizes of an item (an accommodation) history than others reduces the number of user and item to which the collaborative filtering can be applied. To solve it, we introduce a virtual user, who is assumed to rank all of accommodation facilities, to the collaborative filtering, which can increase the number of recommendable user-item pairs. We design the virtual user by

analyzing an actual data set of accommodation. Numerical experiments show the virtual user can increase the number of change on user-item pairs which is recommendable without the virtual user.

[naruse-04:2012] T. Suzuki and K. Naruse. Robustness of Walking by Semi Passive Biped Model on Level Slip Surface. In *Proc. of SICE Annual Conference 2012*, pages 1691–1694, 2012.

Passive Dynamic Walking can descend a shallow slope only using an initial velocity and the gravity. It has good energy efficiency because it does not require any actuator. However, it has been known it cannot walk on level surface. Therefore, the semi Passive Dynamic Walking has been developing. These researches ware focused on a level surface or a downslope. However, a slip occurs at feet in real environment, which makes significant changes on robot states and a robot cannot walk stably. The objective of this paper is to investigate a gait performance of semi passive dynamic walking model on the level slip surface. The objective of this paper is to investigate a gait performance of semi passive dynamic walking model on the level slip surface. We define the occurrence of slip stochastically. We evaluate gait performance of semi Passive Dynamic Walking model with walking duration on a slip surface. As a result, we have shown that the semi passive dynamic walking model can walk on a slip surface with the simple control.

[naruse-05:2012] Jun Kanno and K. Naruse. Control of a Passive-Dynamic-Walking-Based Biped Model with Semicircular Feet for a Small Stair Step. In *Proc. of the 5th International Conference on Intelligent Robotics and Applications (ICIRA 2012), Part III, LNAI 7508*, pages 151–160, 2012.

Because a passive dynamic walking (PDW) robot can walk down shallow slopes using only an initial velocity and gravity, PDW robots are energy efficient. To date, they have been investigated only for shallow slopes and flat surfaces. This paper extends the walking environment to include a small stair step. Here, we use virtual PDW for a biped walking model with semicircular feet. This model has many advantages over the simple PDW model. We analyze the relationships between the height of the small stair step and the model's torque values, and between the height and the time taken to return to stable walking. This enables us to characterize the model's walking capability for a small stair step.

[naruse-06:2012] H. Yamamoto and K. Naruse. Control of an Ostrich-Like Knee Joint for a Biped Robot Based on Passive Dynamic Walking. In *Proc.*

of the 5th International Conference on Intelligent Robotics and Applications (ICIRA 2012), Part III, LNAI 7508, pages 103–112, 2012.

Ostriches are the fastest of all bipedal walking animals, with a knee joint that bends in the opposite direction to the human knee. We investigate the various gaits of a bipedal model of an ostrich, developed according to the notion of passive dynamic walking, and compare them with the walking gaits of a human model. In particular, by controlling the model, we can identify relationships between the leg angles, the walking speed, the trajectory of foot points and the energy consumption. Numerical experiments show that the angle of touching the ground is closer to the vertical for the ostrich model than for the human model, which can be better for high-speed walking.

[naruse-07:2012] K. Naruse. Modeling and Analysis of Information Propagation in Multilayered Communities in Twitter. In *Proc. of the 6th International Conference on Soft Computing and Intelligent Systems and The 13th International Symposium on Advanced Intelligent Systems*, pages CD–ROM, 2012.

Twitter is one of the largest social network services, and it involves only s single social link of follow. However, most of users follow other users in different communities, in which a same tweet is seemed to be distributed different ways. Therefore, information propagation in twitter can be considered as overlaps of single layers of communities. If it is true, we can estimate an information propagation extent of a tweet from the combination of information propagation models for the single layers extracted from actual tweets. In this paper, we assume that a single layer can be represented by a weighted adjacency matrix and the combination of the single layers is modeled as the addition of the matrices. Then, the objective of this paper is to develop a method to represent the matrices and the combination and verify the accuracy of the model. We investigate the method with actual tweets and show it is valid enough.

[naruse-08:2012] K. Naruse. Velocity Correlation in Flocking with Different Motion Model Robots. In *Proc. of 2012 IEEE/SICE International Symposium on System Integration*, pages CD–ROM, 2012.

Most of robotic systems introduce a directionless neighborhood area, such as a circle or sphere, for robot communication and interaction because it reflects a natural property of some physical sensors and devices. On the other hand, it has reported that some of natural birds employ directional neighborhood for neighbor observation. In this paper, we introduce the directional neighbor to

a robotic swarm system, and we investigate how it affects to the connectivity and stability of the system.

[oka-01:2012] Takashi Matsuzaki, Yuichi Yaguchi, and Ryuichi Oka. Occlusion Robust Recognition and Tracking of Motion Objects. In *The 3-rd International Workshop on Bechmark Test Schemes for AR/VR Geometric Registration and Tracking Method*, pages 24–27, November 2012.

This paper presents some results of work on recognizing and tracking moving objects in a movie using Time/Space Continuous Dynamic Programming (TSCDP). Traditional methods for tracking objects, such as Kalman ?lters and particle ?lters, are not robust in cases involving occlusion or multiple objects, and are poor at determining the appearance period for an object in a scene. Moreover, conventional methods for recognizing motion have dif?culty with complex backgrounds because they are based on time?space local features. However, the proposed TSCDP method is effective for both trajectory detection and object recognition. This is because TSCDP carries out optimal and segmentation-free matching (spotting) between a reference time?space pattern representing a category and an unbounded stream of input moving images, in which it recognizes the category. Experiments show that our method works very well for spotting recognition and tracking of moving objects for cases involving multiple objects and occlusion.

[yaguchi-03:2012] Ryuichi Oka Yuichi Yaguchi. Spherical visualization of image data with clustering. In *Awareness Science and Technology (iCAST), 2012 4th International Conference on*, pages 200–206, Seoul, Korea, August 2012. IEEE.

This paper proposes to aid the search for images by visualization of the image data on a spherical surface. Many photographs were lost in the Tohoku tsunami, and those that were eventually found are now being scanned. However, the owners of the lost photographs are finding it difficult to search for their images within a large set of scanned images that contain no additional information. In this paper, we apply a spatial clustering technique called the Associated Keyword Space (ASKS) projected from a three-dimensional (3D) sphere to a two-dimensional (2D) spherical surface for 2D visualization. ASKS supports clustering, and therefore, we construct an image search system in which similar images are clustered. In this system, similar images are identified by color inspection and by having similar characteristics. In this way, the system is able to support the search for images from within a huge number of images.

[yaguchi-04:2012] Ian Wilson Yuichi Yaguchi, Naoya Horiguchi. Finding phoneme trajectories in a feature space of sound and midsagittal ultrasound tongue images. In *Awareness Science and Technology (iCAST), 2012 4th International Conference on*, pages 156–162, Seoul, Korea, August 2012. IEEE.

Supporting the development of a pronunciation learning system, this paper reports an inspection of the trajectory of speech sentences in a feature space that is constructed from midsagittal tongue images and frame-wise speech sounds. One objective of this research is to estimate tongue shape and position from speech sounds, so we focus on determining how best to construct and interpret a feature space we call MUTIS (midsagittal ultrasound tongue image space). Experimental results indicate that higher dimensions of MUTIS are most effective for separating people, and that primarily the lower dimensions of VSS (vocal sound space) data are most effective for separating phonemes. Also, the trajectories within only the VSS data indicate clear differences between first language and second language speakers, but they do not do so within only the MUTIS data. These results indicate that the ultrasound tongue image expresses individual oral cavity over a wide area, and specific tongue shape has a lower contribution in ultrasound tongue images.

[yaguchi-05:2012] Yutaka Watanobe Ryuichi Oka Takeshi Sasaki, Yuichi Yaguchi. Extracting a spatial ontology from a large Flickr tag dataset. In *Awareness Science and Technology (iCAST), 2012 4th International Conference on*, pages 91–97, Seoul, Korea, August 2012. IEEE.

We propose an easy framework for automatically constructing spatial ontologies that locate related concepts together in a space. The conventional graph representation is strong in showing direct relationships between entities, but it is difficult to process its topology when extracting features from the network, because similarity between networks is not well determined. Spatial ontologies are easy to cluster and classify according to the similarities or relationships between entities. We propose a method for creating a spatial ontology called " Associated Keyword Space " and apply it to 0.4M tag words collected from more than 1M images in Flickr. Tags in Flickr have many unknown word tags, but the spatial ontology can explain the clusters of meaning including unknown word tags. The results show that these unknown word tags can be found from neighbor tags that have clear meanings. As a result, an " area ontology " can be explained from the spatial ontology.

[yaguchi-06:2012] Junko Tazawa, Yuichi Okuyama, Yuichi Yaguchi, Toshiaki

Miyazaki, Ryuichi Oka, and Kenichi Kuroda. Hardware Implementation of Accumulated Value Calculation for Two-Dimensional Continuous Dynamic Programming. In *2012 IEEE 6th International Symposium on Embedded Multicore SoCs*, pages 8–15. IEEE, September 2012.

We propose an efficient hardware accelerator for the calculation of accumulated values of two-dimensional continuous dynamic programming (2DCDP). The 2DCDP is a powerful optimal pixel-matching algorithm between input and reference images which can be applied to image processing, such as image recognition, image search, feature tracking, 3D reconstruction, and so on. However, it requires large computation time due to its time and space complexities of $O(N^4)$. We analyze the computation flow of the 2DCDP algorithm and propose a high-performance architecture for a hardware accelerator. Parallelized accumulated minimum local distance calculators and a toggle memory structure are newly introduced to reduce the computation cost and memory. The proposed architecture is implemented into an FPGA, Stratix IV, EP4SE820. Its maximum operation frequency is 125.71 MHz. The preliminary evaluation reveals that the parallel processing by 32 PEs for the accumulated value calculation for 32x32 input and reference images can be sped up to 77 times at the maximum operation frequency of 100 MHz compared to the processing with a multi-core processor.

[yaguchi-07:2012] Yuichi Yaguchi Keitaro Naruse, Emika Sato. Development of accommodation facility selection recommendation system. In *Awareness Science and Technology (iCAST), 2012 4th International Conference on*, pages 207–211, Seoul, Korea, August 2012. IEEE.

A collaborative filtering recommends a list of items to a given user, to which he is expected to prefer to, considering a history of purchase items of the user and those of other users, and it is applied to many web shopping sites. On the other hand, although many people often reserve accommodation facilities from web pages, it is difficult to apply the collaborative filtering to accommodation selection because a smaller sizes of an item (an accommodation) history than others reduces the number of user and item to which the collaborative filtering can be applied. To solve it, we introduce a virtual user, who is assumed to rank all of accommodation facilities, to the collaborative filtering, which can increase the number of recommendable user-item pairs. We design the virtual user by analyzing an actual data set of accommodation. Numerical experiments show the virtual user can increase the number of change on user-item pairs which is recommendable without the virtual user.

Summary of Achievement

Unrefereed Papers

[naruse-09:2012] M. Kinoshita T. Mitamura K. Naruse T. Niwa, K. Yukawa and T. Kawakami. Music evaluation model for automatic composition system. In *SI 2012*, 2012.

[naruse-10:2012] R. Ogata and K. Naruse. Information propagation in social networks represented in multiple layers. In *FAN Symposium*, 2012.

[naruse-11:2012] J. Kanno and K. Naruse. Passive-dynamic-walking-based control of a biped model with semicircular feet for a small stair step. In *JSPE 2012 Fall*, 2012.

[naruse-12:2012] T. Sato and K. Naruse. Analysis of Swarm Maintenance Characteristic for Gyrating Multi-robots. In *JSME Robotics Mechatronics 2012*, 2012.

[naruse-13:2012] K. Tamura and K. Naruse. Development of differential wheel mobile robot in loose soil environment. In *JSME Robotics Mechatronics 2012*, 2012.

[naruse-14:2012] S. Fukui and K. Naruse. Analysis of the Operating Limit of a Swarm Robot Localization System with. In *JSME Robotics Mechatronics 2012*, 2012.

[naruse-15:2012] H. Yamamoto and K. Naruse. Passive-dynamic bnased control of ostrich-like biped walking robot. In *Robot Society of Japan*, 2012.

[naruse-16:2012] R. Ogata and K. Naruse. Information propagation in social networks represented in multiple layers. In *FAN Symposium*, 2012.

[naruse-17:2012] A. Maruyama and K. Naruse. Motion Control of Differential Wheels Robot in Paddy Filed Environments. In *SI 2012*, 2012.

[naruse-18:2012] K. Naruse I. Suzuki S. Haramaki T. Satake, A. Hayashi. Composition of Kinematics for Ultra Redundant robots by Decomposition of Kinematics Calculation Processes. In *SI 2012*, 2012.

[naruse-19:2012] Y. Fukaya and K. Naruse. Visualization of Agent Motions in Large Scale Swarms. In *SI 2012*, 2012.

[naruse-20:2012] K. Naruse. Inverse Kinematics for Hyper Redundant Robot Arms Using Truck-Trailer Kinematics Model. In *JSPE 2013 spring*, 2013.

[naruse-21:2012] M. Kinoshita T. Mitamura K. Naruse T. Niwa, K. Yukawa and T. Kawakami. Music evaluation model for automatic composition system. In *SI 2012*, 2012.

[oka-02:2012] Takashi Matsuzaki, Yuichi Yaguchi, and Ryuichi Oka. Segmentation-free and Occlusion Tobust Recognition adn Tracking of Moving Objects. In *Proceedings of MIRU2012*. IEICE, August 2012.

[oka-03:2012] Yuki Yokokura, Jun Ma, Yuichi Yaguchi, and Ryuichi Oka. Retrieval of Similar Images Using Pixel Correspondence Features. In *Proceedings of MIRU2012*, August 2012.

[oka-04:2012] Ryuichi Oka. Sequence Number-free Dection of Similar Sequences Among Multiple Sequences. In *IEICE Technical Report, PRMU2012-172*, pages 197–203. IEICE, March 2013.

[oka-05:2012] Ryuichi Oka and Takashi Matsuzaki. Robustness for Time-spatial Deformation and Occlusion Realized in Time-Space Continuous Dynamic Programming. In *The papers of Joint Technical Meeting on Information Processing and Innovative Industrial System*, pages 57–63. IEE Japan, August 2012.

[oka-06:2012] Yasutaka Kihara, Takashi Matsuzaki, Yuichi Yaguchi, and Ryuichi Oka. Robust Tracking of MOving Object. In *The papers of Joint Technical Meeting on Information Processing and Innovative Industrial System*, pages 51–56. IEE Japan, August 2012.

[yaguchi-08:2012] 横倉佑紀，馬駿，矢口勇一，岡隆一. ピクセル対応による特徴を用いた類似画像検索. In 画像の認識・理解シンポジウム（*MIRU*）*2012*, number IS1-37, August 2012.

[yaguchi-09:2012] 岡隆一 松崎隆, 矢口勇一. セグメンテーションフリーかつオクルージョンに頑健な物体の動き認識とトラッキング. In 画像の認識・理解シンポジウム（*MIRU*）*2012*, number IS1-36, August 2012.

[yaguchi-10:2012] 岡隆一 松崎隆, 矢口勇一. セグメンテーションフリーかつオクルージョンに頑健な物体の動き認識とトラッキング. In 画像の認識・理解シンポジウム（*MIRU*）*2012*, August 2012.

[yaguchi-11:2012] ウィルソン イアン 矢口 勇一, 堀口 尚哉. 発音習得のための超音波舌画像に対する音素片マッピング. In 電子情報通信学会技術研究報

告. *PRMU,* パターン認識・メディア理解, volume 111, pages 149–154, February 2012.

Grants

[yaguchi-12:2012] Hideki Washiyama Yuichi Yaguchi. 震災遺失写真の返却に資する画像クラスタリング及びビジュアライズ手法の評価, 2012.

[yaguchi-13:2012] Yuichi Yaguchi. 情報地球儀 : 球面クラスタリングによるデータの関係の可視化, 2012-2013.

Academic Activities

[naruse-22:2012] Keitaro Naruse, 2012.

IPSJ Tohoku branch committee

[naruse-23:2012] Keitaro Naruse, 2012.

Session Organizer, SICE SI Division Conference

[naruse-24:2012] Keitaro Naruse, 2012.

iCast 2011 Program committee

[naruse-25:2012] Keitaro Naruse, 2012.

HC2012 Organizing committee

[naruse-26:2012] Keitaro Naruse, 2012.

SCIS-ISIS 2012 Program committee

Patents

[naruse-27:2012] K. Naruse. Estimation system, method, and program for the number of users, 2012.

[oka-07:2012] Ryuichi Oka. Device and Program for Motion Image Processing Application No. Tokugan : 2012-163332 Japan., July 2012.

[oka-08:2012] Ryuichi Oka. Device and Program for Extracting Similar ntervals Application No. Tokugan : 2013-024166 Japan., Feburary 2013.

Ph.D and Others Theses

[naruse-28:2012] Kazuma Suzuki. Master thesis, Graduate School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-29:2012] Takayuki Suzuki. Master thesis, Graduate School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-30:2012] Tatsuya Sato. Master thesis, Graduate School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-31:2012] Atsunori Maruyama. Graduation thesis, School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-32:2012] Yuseke Fukaya. Graduation thesis, School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-33:2012] Ryo Ogata. Graduation thesis, School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-34:2012] Kenta Goto. Graduation thesis, School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

[naruse-35:2012] Shotaro Noguchi. Graduation thesis, School of Computer Science and Engineering, 2012.

Thesis Advisor: K. Naruse

Summary of Achievement

[oka-09:2012] Takashi Matsuzaki. Segmentation-free Recognition of Point Trajectories of Motion Objects From a Video, University of Aizu, 2012.

Master Thesis Advisor: Ryuichi Oka

[oka-10:2012] Toshimitsu Suzuki. Three-dimensional Continuous Dynamic Programming, University of Aizu, 2012.

Master Thesis Advisor: Ryuichi Oka

[yaguchi-14:2012] Shunsuke Wada. A Mining Technique for The Time-Series Data on The Web, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi

[yaguchi-15:2012] Erina Suzuki. Considering Clothing Coordination Map for Enjoying Dress Up, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi

[yaguchi-16:2012] Junpei Koyama. A Visualization of Free Viewpoint TV System using Unified Modeling Language, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi

[yaguchi-17:2012] Kazuhiro Hoshi. A study of Entire Shape Reconstruction Method for Free Viewpoint TV System, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi

[yaguchi-18:2012] Keigo Amma. Gesture Recognition with Single USB-Camera using Time-Space Continuous Dynamic Programming, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi

[yaguchi-19:2012] Keita Sano. First-Language and Second-Language Phoneme Trajectories in Sound and Tongue-Image Feature Spaces, University of Aizu, 2012.

Thesis Advisor: Y. Yaguchi